APOLLO 12

LUNAR SURFACE MAGNETOMETER ANOMALIES

INVESTIGATION OF FAILURE OF ALL SENSOR CHANNELS

DURING EACH LUNAR NIGHT

SSM-13-1399

4.0

AMES
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JUNE 4, 1970

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4.0 LOW TEMPERATURE FAILURE OF X, Y, Z SENSOR CHANNELS

4.1 Introduction

This review has been undertaken to determine the probable cause of the magnetometer failure which first occurred on December 11 at low temperature during lunar night. On that date with the electronics system temperature at -25°C, all channels went abruptly to full scale and remained there until the electronics system temperature rose to -14°C on December 18, the start of the second lunar day. This same failure has since recurred at low temperature on each succeeding lunar night.

The summary of the investigation of temperature failure and of corrective measures is as follows:

- 1.3 Description of anomaly and conditions of occurrence.
- 4.2 Description of possible causes.
- 4.3 Isolation of most probable cause or causes.
- 4.4 Identification of corrective action.
- 4.5 Proposed plan for implementing corrective action, including test validation.

The cause of this failure has been fairly well identified within the instrument to a specific circuit path within the calibrate-offset bias generator. The failure has been simulated, using the breadboard instrument. No other failure mode exists which could have produced the identical effects observed.

4.2 ANALYSIS AND POSSIBLE CAUSES

At 345.20.37.55.1 (11 December 1969) the sensor outputs on all channels started to go to full scale saturation simultaneously. Data sheets showing the system conditions before and after the initial anomaly are attached. The sensor electronics temperature at the time of the failure was 24.6°C. Scientific data for the remainder of the lunar night was lost until 18 December 1969 when the electronics temperature rose to -14°C at which normal operation was again achieved. This same anomaly has occurred on each subsequent lunation when the electronics temperatures go below approximately -24°C.

Following the initial anomaly the instrument was turned off and on again. At this time all channels went to full saturation positive while at the time of the anomaly the X and Y channels went positive and the Z channel went to saturation negative. In addition offset commands were transmitted, the digital filter was bypassed and no change was observed in the anomalous condition.

The simultaneity of the anomalous behavior in all three channels, the nature of the anomalous behavior in the channels and the results of the tests conducted by command of the instrument indicated that the anomaly was due to a failure in the circuitry which was common to all three channels in the sensor electronics. The only point common to all three channels in the sensor electronics is in the Cal/Offset Bias Generator - Summing Network Module. Figures 1, 2 and 3 depict the pertinent parts of the sensor channel electronics used to isolate the failure. An open in the feedback channel will typically drive the channel to full scale saturation. The direction of the drive to saturation being dependent on

the state of that channel alone at the time the open occurs provided the open occurs in those portions of the channel circuitry independent of the other two channels. The drive to full saturation positive of the X and Y channels and the drive of the Z channel to full saturation negative when it was initially indicating a positive reading prior to the failure indicated that there was some outside stimulus (outside the Z channel electronics) causing the Z channel to go to negative saturation. A single open affecting all three channels simultaneously could only occur in the lead from the analog ground on the motherboard to riser 16 on the-14 board to riser 16 on the -13 board and the jumper from riser 16 to riser 8 on the -13 board. Possible opens which could cause the anomaly are indicated on the Figures. An open in this lead would also provide the path for a stimulus from the X and Y channels to the Z channel to cause that channel to drive to full scale saturation negative and not positive. Analysis showed that lifting the analog ground at any one of the above points tied all three channels to a floating node. In this situation there can be an interaction among the channels such that a difference in the magnitude of the currents in the channels can result in the channels having the greater values forcing the channel with the lowest value to go to full scale in the opposite direction. In view of the simultaneity of failure and the requirement that interaction of channels following the failure be maintained, it was concluded that the only failure mechanism which satisfied these conditions was the open previously described.

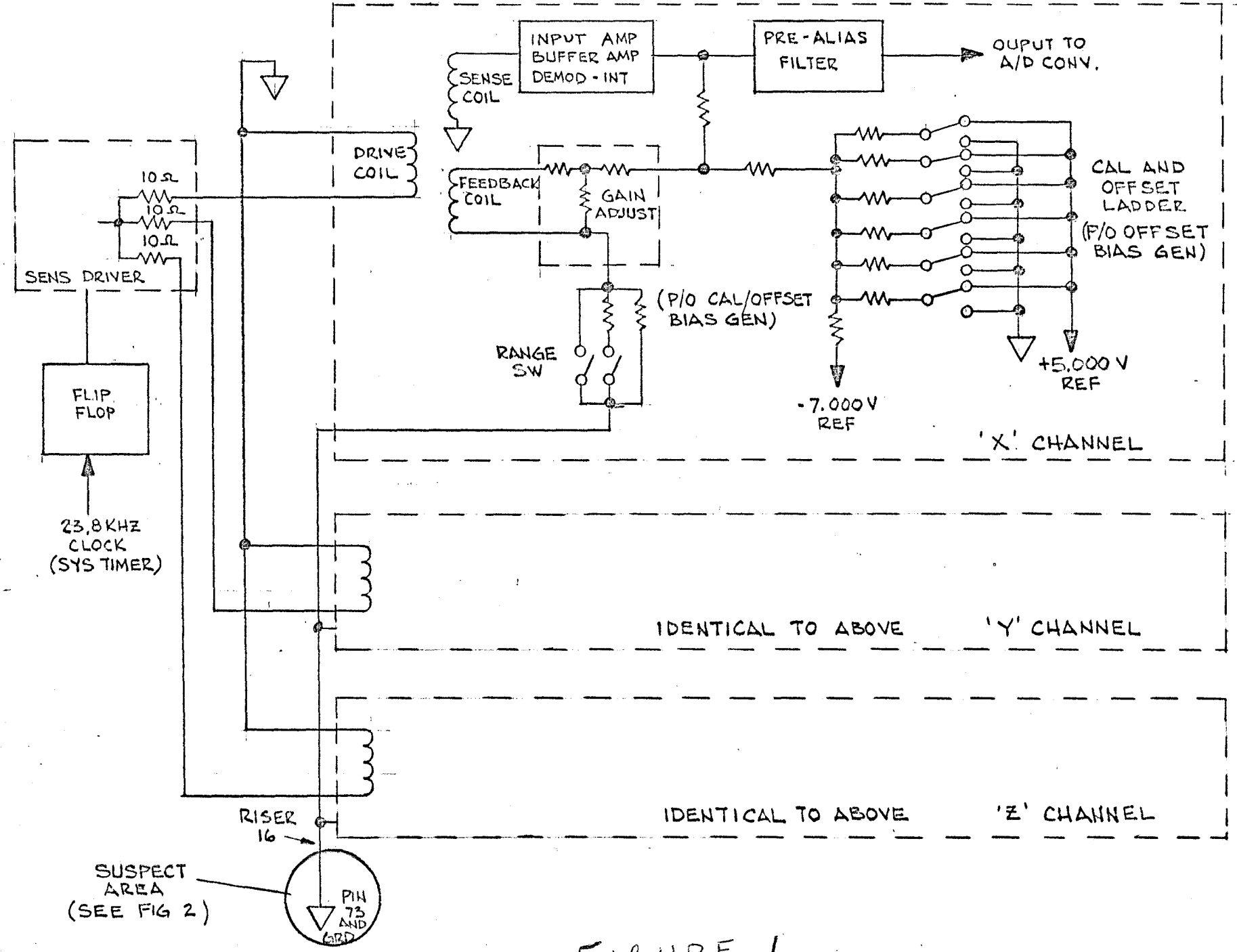

INPUT AMP
BUFFER AMP
DEMOD - INT
PRE-ALIAS
FILTER
OUPUT TO
A/D CONV.
SENSE
COIL
DRIVE
COIL
FEEDBACK
COIL
GAIN
ADJUST
CAL AND
OFFSET
LADDER
(F/O OFFSET
BIAS GEN)
10Ω
10Ω
10Ω
SENS DRIVER
(P/O CAL/OFFSET
BIAS GEN)
RANGE
SW
-7.000 V
REF
+5.000 V
REF
'X' CHANNEL
FLIP
FLOP
23.8 KHZ
CLOCK
(SYS TIMER)
IDENTICAL TO ABOVE
'Y' CHANNEL
IDENTICAL TO ABOVE
'Z' CHANNEL
RISER
16
SUSPECT
AREA
(SEE FIG 2)
PIN
73
AND
GRD

FIGURE 1.

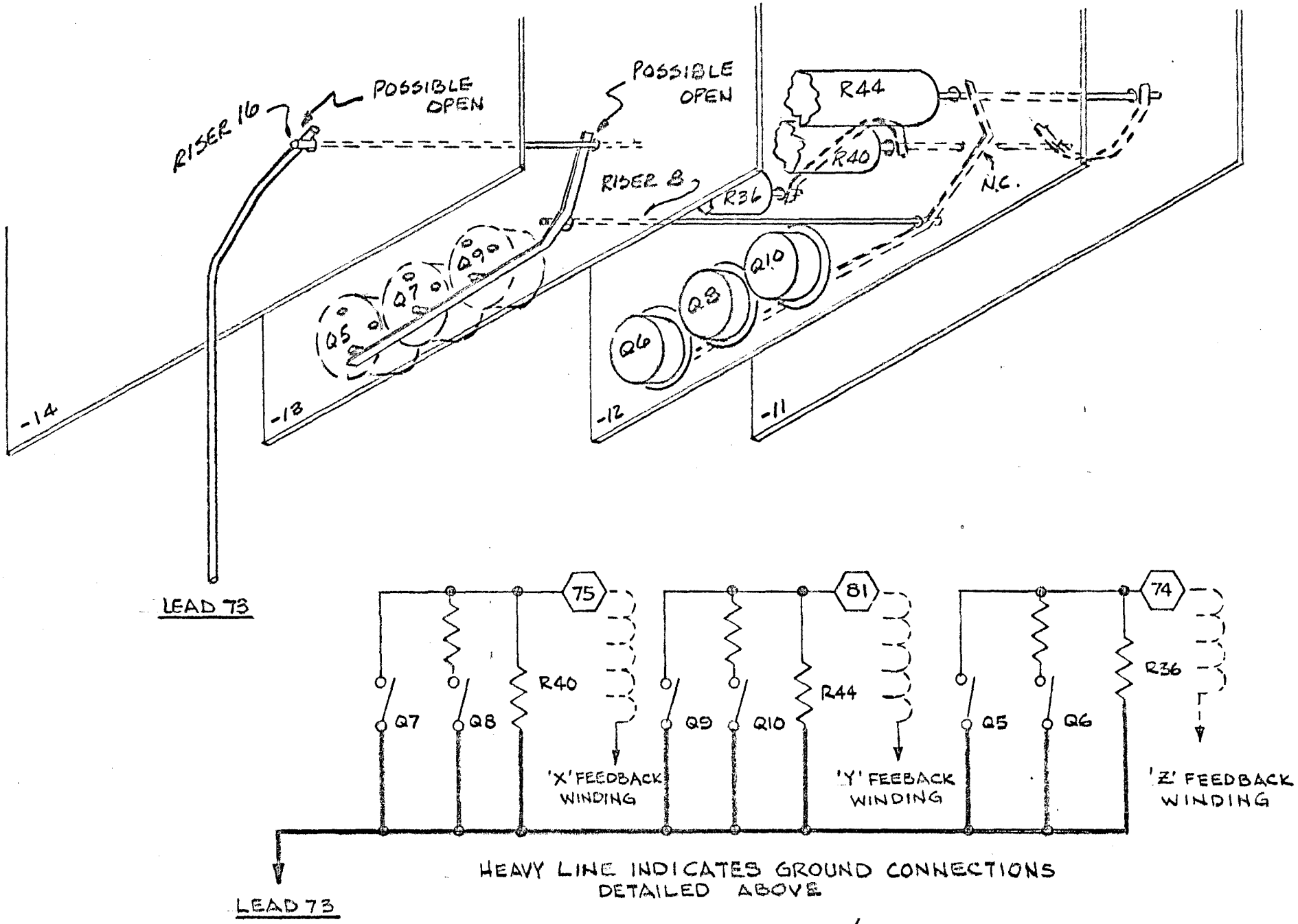
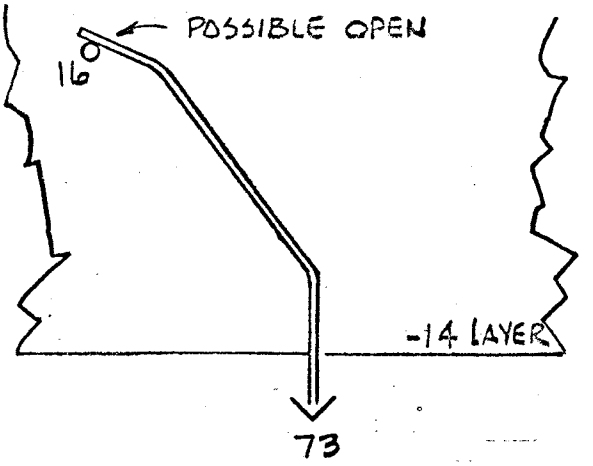
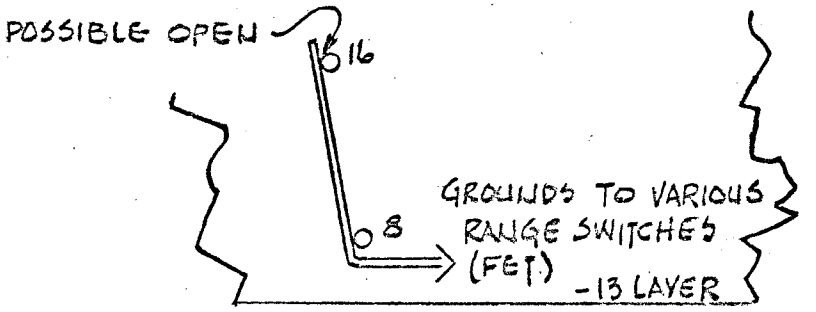


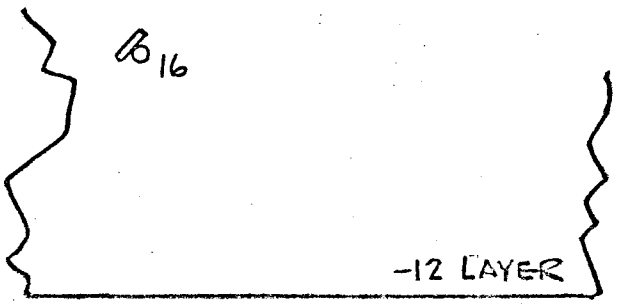
Fig 2 LSM 6 ANOMALY ANALYSIS - DETAIL OF CAL/OFFSET BIAS GEN GROUND



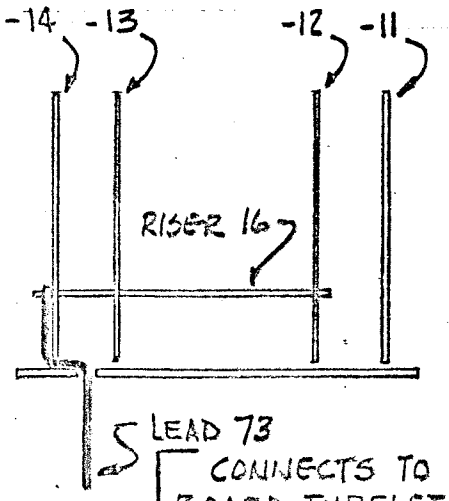
(a.)



(b.)

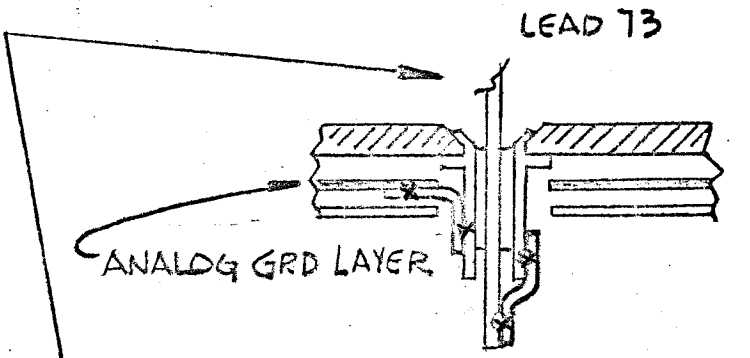


(c.)



CONNECTS TO MULTILAYER BOARD TUBELET WHERE IT PICKS UP ANALOG GROUND

(d.)



* = WELD CONNECTION AND POSSIBLE OPEN

(e.)

ASSEMBLY DETAIL OF SUMMING NETWORK CORDWOOD MODULE (PART OF CAL/OFFSET BIAS GEN) FIGURE 3

4.3 MOST PROBABLE CAUSE OF FAILURE

Analysis of the most probable cause of the failure indicates that the open occurred at one of the four welds on the motherboard indicated by x's in Figure 3e and was due to thermal stressing. Experience on the Pioneer Magnetometer and on the LSM program indicates that the preponderance of opens associated with cord-wood modules occur at the motherboard connections rather than internal to the potted modules. It is concluded that an open circuit at pin 73 on the A1 motherboard is the most likely cause of failure.

4.3.1 Test Verification

Tests were conducted both on the breadboard model of the Lunar Surface Magnetometer at ARC and LSM S/N 007 at Philco-Ford. In these tests it was possible to duplicate the anomalous condition exactly by opening pin 73 on the motherboard of LSM S/N 007 and the equivalent opening on the breadboard model. By varying the drives to each channel prior to the open, the direction of the channel to saturation positive or negative could be controlled.

4.4 CORRECTIVE ACTION

A recently adopted procedure for more intense inspection and rejection criteria for motherboard connections is described under 3.4.2. The procedures are effective. Applied to LSM #7, no failures due to opens at the motherboard connections occurred during instrument checkout following assembly, pre-acceptance test and acceptance test.

The past history of motherboard pin failures associated with extreme temperature environments and the circumstances of the failure in this instance strongly indicates that temperature stressing caused an ultimate rupture of a marginal pin/tab weld connection. Corrective measures described under 2.3, 3.4.3 and 3.5.4 will mitigate such thermal stresses. Additional instrument temperature tests to levels in excess of those anticipated on the lunar surface are now conducted as noted in Paragraph 3.5.3.